BAST FIBER CROPS
HARVESTING
by Luigi Pari
CRA-ING
- Introduction to bast fiber crops

- Existing harvesting systems for the following species:
  Flax (*Linum usitatissimum* L.)
  Hemp (*Cannabis sativa* L.)
  Kenaf (*Hibiscus cannabinus* L.)

- Some basics of harvesting for the following species:
  Jute (*Corchorus olitorius* L. and *C. capsularis* L.)
  Nettle (*Urtica dioica* L.)

- Concluding remarks

- Future activities
What is the bast fiber?

The bast fiber comes from the phloem tissue of the plant. It provides support to the conductive cells of the phloem and strenght to the stem.
How is the bast fiber extracted? The importance of retting

The separation of the bast fiber from the xylem tissues of the plants is carried out through specialized machineries in the scutching line. However, this process is possible only after that the plants are retted.

What is retting?

It is a phenomenon occurring through the combined action of bacteria and weathering which allows the degradation of the stem material (mainly pectines) surrounding the fibre bundles.

Once the retting is completed, the plants are ready for bailing.
Retting methods

1) **Dew retting**: is most effective in climates with heavy nighttime dews and warm daytime temperatures. In this procedure, the harvested stalks are windrowed in the field, where the combined action of bacteria, sun, air, and dew produces fermentation, dissolving much of the stem material surrounding the fibre. Within two to three weeks, depending upon climatic conditions, the fibre can be separated. Dew-retted fibre is generally darker in colour and of poorer quality than water-retted fibre.
2) **Water retting**: bundles of stalks are submerged in water. The water, penetrating to the central stalk portion, swells the inner cells, bursting the outermost layer, thus increasing absorption of both moisture and decay-producing bacteria.

Retting time must be carefully judged; under-retting makes separation difficult, and over-retting weakens the fibre.

Natural water retting employs stagnant or slow-moving waters, such as ponds, bogs, and slow streams and rivers. The stalk bundles are weighted down, usually with stones or wood, for about 8 to 14 days, depending upon water temperature and mineral content.
Variants of water retting

**Tank retting:** allows greater control and produces more uniform quality. The process, usually employing concrete vats, requires about four to six days and is feasible in any season. In the first six to eight hours, called the leaching period, much of the dirt and colouring matter is removed by the water, which is usually changed to assure clean fibre. Waste retting water, which requires treatment to reduce harmful toxic elements before its release, is rich in chemicals and is sometimes used as liquid fertilizer.

**Double retting:** a gentle process producing excellent fibre, the stalks are removed from the water before retting is completed, dried for several months, then retted again.
Harvesting bast fiber crops is a difficult task for the following reasons:

1) High heterogeneity among crops that require different harvesting technologies
2) Difficulties to preserve the fiber quality during the harvesting operation
3) Ensuring the fiber separation at the processing facility.
Harvesting hemp: general features

Hemp is a taproot annual herbaceous plant with erect stem reaching over 4 meters in height. It grows best in zones with temperate climate (13-22° C) and is suitable for cultivation in temperate zones, in the mediterranean and in the sub-tropics. Hemp crops for fibre production are traditionally harvested at full flowering of male plants which is when primary bast fibre yield reaches its maximum. Fiber hemp may yield up to 25 t of dry matter per hectare (20 t stem dry matter ha-1). Stalks average around 20-30% of bast fiber.
Harvesting hemp: general features

Hemp can be cultivated to obtain long and short fiber. The material produced, which can be used in different production chains, requires in turn different harvesting techniques. For this reason, the hemp harvesting can be divided in two categories

1) Longitudinal harvesting: for obtaining long fibers for textile production

2) Disordered harvesting: for obtaining short fibers for technical uses
Important basic concepts

Nowadays, the experience gained in the harvesting technologies led to develop some basic concepts that must be taken into account during the field operations. These are:

- ensuring a uniform field drying and retting after mowing
- having a low liability to weather conditions
- ensuring an efficient swath handling (turning and windrowing)
- ensuring that the baled product is ready for the further steps of processing and manufacturing

It is not easy to comply with all these basic concepts during the harvesting operations. In fact, each machine has determined characteristics that respond just in part to these requirements
Longitudinal harvesting: problems

Nowadays, the traditional hemp processing lines are considered very old and inefficient, since they require a lot of handiwork and high processing costs. To solve in part this problem, the cultivation or the harvesting techniques for long hemp fiber production have to be adapted to that of flax in order to use modern flax scutching lines also on hemp stems.

However, the harvesting systems capable to furnish processable material to the flax scutching lines are still limited. This is because the features of the hemp plants differ from those of flax; the main limit is given by the height of the plants that in hemp is generally twice than flax.
The CRA-ING experience on longitudinal harvesting

The past experience of CRA-ING demonstrated that flax turner and balers can be utilized to collect windrowed hemp.

Depoortere single turner tested on windrowed hemp

Dehondt baler tested on windrowed hemp
Depoortere single turner tested on windrowed hemp

Dehondt baler tested on windrowed hemp
The workability of the hemp baled material at the flax scutching lines was verified.

The CRA-ING experience on longitudinal harvesting

The tests indicated that the flax scutching machines can process hemp with acceptable yields.

<table>
<thead>
<tr>
<th>Hemp scutching performance</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long fibre</td>
<td>8,82</td>
</tr>
<tr>
<td>Short fibre</td>
<td>17,03</td>
</tr>
<tr>
<td>Tow</td>
<td>3,18</td>
</tr>
<tr>
<td>Pith</td>
<td>70,97</td>
</tr>
</tbody>
</table>
The CRA-ING experience on longitudinal harvesting

However, our study has shown a missing link in the hemp harvesting chain as well.

In fact, it is still to be developed an hemp harvester/windrower machine that may produce and arrange in ordered swaths the hemp stem sections to be turned and baled with flax machines.
Disordered hemp harvesting

In the disordered harvesting the plants are cut in pieces generally smaller than 1 m. These are arranged disorderly in windrows and then baled with traditional balers. There are three systems that are basically used to harvest hemp.
1st system: rotary header with cutting drum
HempCut 3000 or 4500

The HempCut machine consists of a row independent rotary header made by Kemper (Stadtlohn, Germany) combined to a Claas Jaguar 830 presenting a one-knife cutting cylinder developed by HempFlax. The hemp stalks are mowed by the header and fed lengthwise into the chopping drum, cut into 600 – 700 mm long pieces, and placed onto the field directly under the drum.

Limits: repeated swath turning is necessary to ensure a uniform retting process.
2nd system: counterrotating drums with cutting disks “Bluecherho 02/03”

Developed in 1990’s by the company Kranemann (Germany).

The basic idea of the Bluecherho is to preserve the original array of the hemp plant until it is cut into pieces of 600 – 700mm.

Initially, the conveyor elements maintain and collect hemp stalks in a vertical position. Then the cutting units (discs), located at fixed positions on the drum, cut the stalks kept upright in their natural position several times before setting them in a swath.

Limits: imperfect forms of the swaths generated which may influence negatively the retting and drying phase.
3rd system: Cutting bars "Clipper 4.3 MMH"

Developed by the company Tabeco (Czech Republic), the system is composed by simple cutting bars mounted at three different height onto a metallic frame driven and powered by tractor. The three cutting bars are 4 m long. They cut the stems down into parts of 1000 millimeters about. In this case the cut material occupy the full field area (wide swath), this makes faster and more homogenous the retting and field drying.

Limits: it requires repeated turning and windrowing
Resuming table of the machine performances and characteristics

<table>
<thead>
<tr>
<th></th>
<th>HempCut 3000/4500</th>
<th>Bluecher 02/03</th>
<th>Clipper 4.3 MMH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power requirment (Kw)</td>
<td>250</td>
<td>100</td>
<td>74</td>
</tr>
<tr>
<td>Working speed (Km/h)</td>
<td>5 to 10</td>
<td>5 to 12</td>
<td>12.5 to 16.6</td>
</tr>
<tr>
<td>Area Performance (ha/h)</td>
<td>2,1-3,4</td>
<td>2,9</td>
<td>4 to 5</td>
</tr>
<tr>
<td>Swath width (mm)</td>
<td>800</td>
<td>800</td>
<td>(no swaths, uniform layer)</td>
</tr>
<tr>
<td>Maximumum working widht (mm)</td>
<td>3000 or 4500</td>
<td>3500</td>
<td>4000</td>
</tr>
</tbody>
</table>

Studies show that among the existing commercial machinery above described, the multiple level cutter bar system has improved the retting behavior of the stems. However, there is still a need to improve the harvesting systems in order to cut and prepare properly the hemp stems for subsequent storage and processing.
Combined Harvesting (seeds and fibre)

A german prototype of a new hemp combine harvester was developed and manufactured until the year 2000. With this machine the hemp plant is mowed from stubble, cut into 600 mm pieces, threshed to separate seeds, and stacked in a swath on the field.

Problems:

• the over mature seeds are lost due to mechanical shaking of the hemp plant by the combine header before being fed into the machine.

• the hemp straw is partly decorticated due to passage of the whole crop through all working elements of the combine, so raw material losses (fibres, shives) are expected.
Baling hemp

The baling can be done with any kind of baler. Large round, soft-core balers may be most satisfactory in allowing bales to dry more quickly in storage. Bales must be stored indoors under dry conditions to stop the retting process before the fibers become rotted. Stalk moisture should be less than 15% at time of baling, and should continue to dry to about 10%
Flax: general features

Flax (*Linum usitatissimum* L., 1753) is an erect annual plant growing till 1.2 m, with slender stems and blu flowers. The fiber produced is twice as strong as that of cotton and five times as strong as that of wool. Harvesting is carried out in August-September, when the plants reach the ideal ripening degree. There are three degrees in the ripening of the flax grown to make linen: green, yellow and brown.

- The yellow has proved to be the most suitable since the fibres are long and supple, and therefore ideal for further processing.

Flax that is pulled too early (green) produces very fine but weak fibres. On the other hand, in overripe flax (brown) the stems are strong but brittle producing much undesirable short fibers.
Harvesting flax: main steps

1) Pulling and windrowning
2) Retting
3) Turning: the plants are turned to ensure the uniform retting. Mainly used for producing fibers of high quality.
4) Baling parallel stems

Dehondt single puller
Union double turner
Dehondt self-propelled baler
1st step "pulling and windrowing"

**Machines:** flax pulling machines are mainly produced by Western European companies such as Dehondt (French), Union, and Depoortere (Belgium)

**Purpose:** plants are pulled from the ground and arranged in windrows. The stems are pulled and not cut in order to preserve the length of the fiber.

<table>
<thead>
<tr>
<th></th>
<th>Company</th>
<th>Model</th>
<th>Weight</th>
<th>Engine</th>
<th>Working width</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single puller</strong></td>
<td>Union</td>
<td>GE200</td>
<td>4700kg</td>
<td>Deutz BF4M1013E 124 hp</td>
<td>144cm</td>
</tr>
<tr>
<td><strong>Double puller</strong></td>
<td>Union</td>
<td>GE220</td>
<td>7150kg</td>
<td>Deutz TDC 2012- 200 hp</td>
<td>240-260 cm</td>
</tr>
</tbody>
</table>
2nd step "turning"

**Machines**: Carried out with turning machines (single turner or double turner) mainly developed by Union, Dehont, Depoortere, and Agromash (Belarus).

**Purpose**: ensuring a uniform retting in order to make easier the fiber extraction

<table>
<thead>
<tr>
<th></th>
<th>Company</th>
<th>model</th>
<th>Weight</th>
<th>Engine</th>
<th>working width</th>
<th>Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single turner</td>
<td>Dehondt</td>
<td>T3R</td>
<td>2300kg</td>
<td>Deutz F3L1011F – 50 hp</td>
<td>100 cm</td>
<td>1Ha/h</td>
</tr>
<tr>
<td>Single turner</td>
<td>Agromash</td>
<td>OL-140</td>
<td>980kg</td>
<td>(semi-trailed)</td>
<td>140 cm</td>
<td>0.85Ha/h</td>
</tr>
</tbody>
</table>
3rd step "baling"

**Machines**: self-propelled or trailed balers produced by Vlamalin, Union, Dehondt

**Purpose**: the balers are designed to form regular flax layers within rolls of parallel stems. The regularity of layers will ensure an easier processing in the next steps.

<table>
<thead>
<tr>
<th>Company</th>
<th>Model</th>
<th>Weight</th>
<th>Engine</th>
<th>working widht</th>
<th>Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baler</td>
<td>Dehondt EAS-EASC</td>
<td>not disp.</td>
<td>John Deere 4045DF270 – 60 kw</td>
<td>100cm</td>
<td>1ha/h</td>
</tr>
<tr>
<td>Baler</td>
<td>Union GE250</td>
<td>5200kg</td>
<td>Deutz F6L914- 130hp</td>
<td>100 cm</td>
<td>Not. disp.</td>
</tr>
</tbody>
</table>

Dehondt self-propelled baler

Union self-propelled baler
Combined harvesting

Flax is cultivated for seeds production too. The seed harvesting can be made with traditional combines, that in a single passage provide reaping, threshing, and winnowing. Once the seeds are separated from the plant, the residual dry leaves and stems are posteriorly downloaded in windrows and then collected in bales and processed.

However, this is type of harvesting is mainly used for producing seeds. In fact, the fibrous material obtained in this process has low quality and therefore limited use (no textile industry or in other production chains that require high quality fiber). In Saskatchewan region (Canada) sometimes it is even burned by farmers because the costs for handling and transport are higher than profits.
Innovative machineries for combined harvesting of flax (seeds and fiber)

The company Union has developed new machines "turner-deseeders" which are able to turn the windrows, ensuring a uniform retting and high quality fibers, collecting seeds at the same time.

Union trailed turner-deseeder. The material is unloaded in trailers bring by tractors during the machine progress.

Union self-propelled turner-deseeder. The material is unloaded in trailers once the seed tank is full.
Kenaf harvesting: general features

Kenaf is an annual or biennial herbaceous plant growing to 1.5-3.5 m tall with a woody base. The stems’ diameter is 1–2 cm, it contains a bast fiber portion comprising 26 - 35% (by dry weight). The average length of the fiber is 2.5 mm providing a desirable blend for many pulp and paper applications. Other uses of the kenaf bast fiber include cordage, composite materials, and coarse cloth.
Kenaf harvesting: general features

According to the end use of the crop, kenaf can be harvested as green or dry material. The first is harvested during flowering, while the dry material during winter, when the death plans are still erect in the field, leafless, and present the stems degraded by atmospheric and biologic processes. There are advantages and disadvantages in using a product respect another; in any case it is widely accepted that fibers coming from green material are more valuable and can be used for more purposes.
Systems

1) Sugarcane-type Harvesters.

2) Jute/reed-type harvesters

3) Forage-type Harvesters and Baling Equipment.

4) F.lili Bassi
Sugarcane-type harvesters.

These are unmodified or slightly modified sugarcane harvesters that use rotating knives or circular cutting blades to chop off the base of the kenaf stalk and to separate the low fiber from foliage and top portions of the plants. The long stalks then pass through the equipment upright and then are laid down in long windrow to field-dry.
A prototype of modified sugarcane harvester was tested in Japan in 2003. The machine with a modified rotating knives system has shown a good productivity, being able to harvest green and dry stems. Beside the modified cutting system, the machine was equipped with a chopper system producing green-stem, leafless, 20-22 cm long. The leaves, removed with rollers during the machine progress were then blown out with a fan. The stem portions were then collected in net bags or loaded onto a trailer.
Jute/reed-type harvesters

Model 4GL-180II developed by the Chinese company Yucheng Yatai Machinery Manufacturing Co.

The machine designed for harvesting jute and reed can be used for kenaf as well. It has a cutting bar system that chop off the stalks in the first 5cm above the ground. After cut the entire plant is directed in the rear part of the machine and left upright onto a metallic support by conveying organs. During the machine progress, the stalks are gradually accumulated on the metallic support and finally laid in windrows.

The machine is powered by a 52 hp engine, the net weight is 2000kg, the working efficiency is 0.68-1 ha/h and the working width is 1800mm.
Forage-type harvesters and baling equipment.

Forage-type harvesters and baling systems have been widely evaluated for use in kenaf production, harvesting, and processing. It has been demonstrated that standard forage cutting, chopping and baling equipment can be used for harvesting kenaf as either a forage or fiber crop.

Kenaf can be baled in both small and large square bales or in large round bales.
Combined harvesting of kenaf (fiber and seeds)

As for hemp and flax, the mechanical harvesting of kenaf can be made with combine machines that allow both seeds and fiber collection (the latter is successively baled). However, the results achieved with the combined harvesting, especially in the fiber quality, are not optimal yet.
Jute harvesting

The model 4GL-180II of the Chinese company Yucheng Yatai Machinery Manufacturing Co. can be utilized for the jute harvesting. The machine (already described in the kenaf section) has an area performance of 0.7ha/h and requires two operators.
Nettle harvesting

Studies show that machines with cutter bars can be adapted for harvesting fiber nettle, but improved harvesting technology for nettle has not yet been developed.

Since the morphological characteristics of nettle stalks are similar to those of hemp, one can assume that the same harvesting machine could be used for both crops.

However, problems, such as the wrapping of fibers around axles of rotating pieces of equipment and breakdown will occur if the machines are not adapted to the harvest of fiber crops.
Final considerations

The existing machines for the flax harvesting are certainly the most effective for both bast fiber harvesting and seeds collection. Indeed, the introduction of machines that perform efficient turning and deseeding at the same time has determined the possibility to maximize revenue (high quality fibers and seeds).

Several problems remain unsolved for hemp and kenaf since the existing technologies are not sufficient to deal effectively with these crops. The reason is due to the plant characteristics, which make difficult the production of high quality fiber as for flax. The same is true for the combined harvesting which showed problems in terms of seed losses and low fiber quality.
Concluding remarks

Promoting the development of fiber crops can help the local economic development, create new jobs, and generate positive environmental benefits, thus contributing to the sustainable development of urban fringe and rural areas.

Technological innovation will be essential to make the existing harvesting machineries suitable for multiple crops, improve fiber quality, and increase the profitability of the chain.
References

Thank you for your attention!

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